Sust. Build. **8**, 5 (2025)

https://doi.org/10.1051/sbuild/2025007

Sustainable Buildings

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ORIGINAL ARTICLE OPEN ACCESS

Reutilization value assessment approach for industrial building heritage based on hierarchical analysis process

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Received: 27 October 2024 / Accepted: 21 August 2025

Abstract. The assessment of industrial building heritage reutilization value (AIHRV) aims to identify and quantify its cultural, economic, environmental and social values, to promote heritage conservation and sustainable development, and to enhance local characteristics and attractiveness. Therefore, this paper proposes an assessment of industrial heritage reutilization value based on the hierarchical analysis method by comprehensively considering eight indicators, including historical value, artistic value, cultural value, social value, scientific and technological value, economic value and environmental value, and 24 indicators, including sustainable value and historical era, cultural symbolism and public participation. Firstly, this paper puts forward the index system of AIHRV (including 8 first-level indices and 24 second-level indices). Secondly, it puts forward the method of AIHRV based on the hierarchical analysis method, including: establishment of the hierarchical standard of AIHRV, establishment of the hierarchical model of AIHRV, construction of the judgment matrix of AIHRV indices, square root method to calculate the maximum eigenvalue of judgment matrix, consistency test for hierarchical single ordering, and hierarchical total ordering, etc. Thirdly, the AIHRV level is obtained by combining the AIHRV level standard with the subjective scoring method and the objective weight assessment method. Finally, the correctness and validity of the proposed method are verified through a case study.

Keywords: Hierarchical analysis / industrial heritage / reutilization assessment methodology / indicator judgment matrix / consistency test for hierarchical single and total ranking

1 Introduction

The assessment of industrial heritage reutilization value (AIHRV) aims to systematically analyze and quantify the value of industrial heritage (VIH) in various aspects, including culture, economy, environment and society [1–4], and to promote its effective protection and rational use. Firstly, it can excavate and pass on historical and cultural values [5], enabling the public to have a deeper understanding and sense of identity of industrial heritage and its backstory, and enhancing local identity. Secondly, from the economic point of view [6], the assessment can identify the potential of heritage reutilization, attract investment, create employment opportunities and promote local economic development. Environmentally, the reutilization of industrial heritage (RIH) can help save resources and reduce waste, promote sustainable development, and reduce the burden of new development projects on the environment. At the same time, it can also bring social benefits to the community by creating cultural spaces and activity venues [7], enhancing the quality of life of residents and community cohesion. Finally, a comprehensive assessment provides a scientific basis for the government and enterprises to make decisions, making them more targeted and feasible in planning and implementing projects. Therefore, the AIHRV is not only related to the protection and utilization of the heritage itself, but also the key to realizing the triple benefits of economy, society and environment.

The current state of research on the AIHRV has gradually gained attention from academia and society in recent years [8,9]. With the acceleration of global urbanization, many industrial heritages are facing abandonment or demolition. In order to protect these assets of historical and cultural values, scholars have conducted a large number of studies to explore the effectiveness and feasibility of their reutilization. Reference [10] discussed the evolution of the cultural heritage protection system on values, policies and practices and emphasized the tendency for industrial heritage to be redefined and managed. Reference [11] analyzed the application of sustainable assessment of built heritage for local industrial heritage, and the sustainability as the base is used to choose some

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indices. Reference [12] proposed an approach for assessing the value of industrial heritage using a Dempster–Shafer theory and stated that industrial heritage has a relationship with political, economic, cultural, social, scientific, technological, and architectural fields. In [13], heritage valuation and spatial compatibility are discussed using the analytic hierarchy process (AHP) for solving the multicriteria problem. Reference [14] used an improved entropy TOPSIS method for evaluating the adaptive reutilization potentiality of industrial heritage and computed the reutilization potentiality values of each hierarchical evaluation index. Reference [15] utilized a review to discuss the frameworks, methodologies, and assessment methods about the adaptive architectural heritage reutilization. For understanding the industrial heritage protection design of iterative reconstruction, reference [16] analyzed industrial heritage protection design through the GA optimization algorithm and iterative reconstruction. For explaining the importance and application value of big data on the industrial heritage planning and decision-making, reference [17] discussed the concept and application of industrial heritage planning and decision-making by big data theory. In [18], Greek industrial buildings are reused for special interest/alternative tourism. In [19], Egyptian National Museum is analyzed as an object to discuss heritage buildings reutilization assessment problem. Reference [20] introduced societal impacts of the restoration and renovation project of industrial heritage. Reference [21] took Romania as example to analyze reutilization models for technical and industrial heritage. The above analysis and discussion revolve around the reutilization of industrial heritage, but there are relatively few studies on the AIHRV, therefore, this paper proposes the reutilization value assessment method for industrial heritage based on the hierarchical analysis method.

The main contributions in this paper are concluded as follows:

- This paper proposed an indicator system for AIHRV, which can fully take into account 8 first-level indices and 24 second-level indices.
- This paper proposes the method of AIHRV based on an analytic hierarchy process, establishes the hierarchical structure model of AIHRV, constructs the judgment matrix of AIHRV indices, calculates the maximum eigenvalue (ME) of the judgment matrix by the square root method, and tests the consistency of the hierarchical single ranking and the hierarchical total ranking.
- Considering the subjective scoring method and the objective weight assessment method, the AIHRV level is formulated, and the correctness and validity of the proposed method are verified through case studies.

2 Index system for AIHRV

This paper proposes an index system for AIHRV, which is used to assess the various VIHs in the process of reutilization, including historical and cultural value, socio-economic value, environmental value, etc. The index system is intended to help decision makers better understand and assess the reutilization potential of industrial heritage, in order to promote the protection and reutilization of industrial heritage, to facilitate the inheritance of cultural values, and to maintain historical memory.

2.1 First-level indices for assessing the VIH

The AIHRV is a process of comprehensively considering various factors such as historical value, cultural value, social value, artistic value, economic value, environmental value, etc. By comprehensively analyzing these factors, the overall value of industrial heritage reutilization can be more accurately determined. This paper proposes the first-level indicators of AIHRV and their connotations as shown in Table 1.

2.2 Second-level indices for assessing the VIH

This paper proposes 24 comprehensive value evaluation indices for industrial heritage reuse based on the structure of eight different types of first-level indices at the decision-making guideline level, constituting a comprehensive value evaluation indices system of industrial heritage, and the system is oriented to the protection and utilization of industrial heritage, which takes into account the requirements of protection as well as the needs of utilization. 24 reutilization value evaluation indices and their definitions for industrial heritage are shown in Table 2.

3 Value assessment approach of industrial heritage reutilization based on the hierarchical analysis

3.1 Grade standard for assessing the VIH

The AIHRV needs to give the assessment scheme, and this paper constructs the AIHRV grade standard, as shown in Table 3, which sets five AIHRV grades, namely: poor ($S < 1.5$), poor ($1.5 \leq S < 2.5$), average ($2.5 \leq S < 3.5$), good ($3.5 \leq S < 4.5$) and very good ($S \geq 4.5$), with full 5 points, and their judgments correspond to no value, low value, medium value, valuable and very valuable.

By combining the grade standard for AIHRV and the expert scoring values of the second-level indices, the actual grade $S(k)$ of AIHRV can be obtained, and the calculation formula is as follows:

$$S(k) = \sum_{i=1}^{N_{FI}} \sum_{j=1}^{N_{SI}} \omega_{ij}(k) \times S_{ij}(k) \tag{1}$$

where N_{FI} and N_{SI} are numbers for first-level indicators and second-level indicators.

3.2 Establishing a hierarchical model for assessing the VIH

The hierarchical structure of AIHRV proposed in this paper consists of a target layer, a middle layer (i.e., the first-level indices layer and a second-level indices layer) and

Table 1. First level indices for assessing the reutilization value of industrial heritage.

Target	First-level indices	Definitions
AIHRV (A)	Historical value (B1)	Assessment of the historical background, architectural style and cultural significance of the industrial heritage to determine its historical and cultural value.
	Cultural value (B2)	Examination of the historical and cultural significance carried by the industrial heritage, including its position in the local society and culture, historical value, traditional craftsmanship, etc.
	Social Value (B3)	Examining the impact of the industrial heritage reutilization project on the society, including community participation, improvement of residents' life, enhancement of social cohesion, etc.
	Artistic Value (B4)	The artistic and architectural uniqueness and aesthetic value of the industrial heritage after its reutilization
	Scientific and technological value (B5)	Assessment of the technical characteristics, technological level of the process, embodied in the industrial heritage.
	Economic Value (B6)	Evaluation of the economic benefits of the industrial heritage reutilization project, including job creation, output value contribution, return on investment, and analysis of the project's contribution to local economic development.
	Environmental Value (B7)	Evaluating the degree of impact of the industrial heritage reutilization project on the environment, including the way of resource utilization, energy consumption, waste disposal, etc., so as to ensure the friendliness of the project to the environment.
	Sustainable Value (B8)	Assess the sustainability of the industrial heritage reutilization project, including the long-term operation, maintenance and management mechanism of the project, so as to ensure the sustainable development of the project.

a strategy layer, as shown in Figure 1. In this hierarchy, the target layer is "the AIHRV"; the intermediate level consists of 8 categories of first-level indices (i.e., B_1, B_2, . . . , B_7, B_8), 24 second-level indices (i.e., C_{11}, C_{12}, C_{13}, . . . , C_{81}, C_{82}, C_{83}) belonging to the first-level indices, and the strategy layer consists of D_1, D_2, D_3, D_4 and D_5.

3.3 Constructing index judgment matrix of for assessing the VIH

Constructing the index judgment matrix of industrial heritage value assessment is the information basis of hierarchical analysis method. Using the judgment matrix and the ranking method, the ranking of the importance of each strategy can be obtained. To reduce the difficulties of comparing factors with different properties and to improve accuracy, this paper utilizes a 9-level scale [22,23] used in the analytic hierarchy process for comparison of factors. The evaluation scale is shown in Table 4.

Through the two-by-two comparison of the industrial heritage value assessment indices of each layer forms its judgment matrix, which is shown in Table 5. In Table 5, S and L are the upper-level criteria and the lower-level criteria to which they belong (e.g., S is the first-level index B_1, and L is the second-level index C_1 to which belongs B_1), and a_{ij} is the result of the comparison of the importance of index i with that of index j. The value of a_{ij} is obtained according to the 9 importance levels and their values listed in the table, and its expression is as follows:

$$a_{ij} = \frac{1}{a_{ji}}. \tag{2}$$

3.4 Computing the maximum eigenvalue of the judgment matrix

In order to carry out the consistency test for judgment matrix, it needs to calculate the ME of the judgment matrix. So, this paper uses the square root method to calculate the ME of the judgment matrix. Let the judgment matrix be $\boldsymbol{M} = (a_{ij})_{n\times n}$, the specific calculation steps of the square root method for calculating the eigenvectors of the judgment matrix are as follows:

S1) Compute the product of the elements of each row in matrix:

$$m_i = \prod_{j=1}^{n} a_{ij},\ 1, 2, \cdots, 3 \tag{3}$$

S2) Calculate the nth root of m_i:

$$\overline{w}_i = \sqrt[n]{m_i},\ 1, 2, \cdots, 3 \tag{4}$$

Table 2. Second-level indices for AIHRV.

First-level indices	Second-level indices	Definitions
Historical value (B_1)	Historical Era C_{11}	The primary historical period during which the industrial heritage site (buildings, facilities, equipment, etc.) was originally constructed, used, or which it predominantly represents.
	Historical background information C_{12}	The detailed information, documents, archives, oral histories, etc., associated with the industrial heritage that elucidate its origin, development, evolution, significant events, operational status, and its relationship with the contemporary social, economic, political, and technological environment.
	Relevance to historical figures and events C_{13}	Measures the level and closeness of the connection between the industrial heritage and significant historical figures or major historical events.
Cultural value (B_2)	Cultural symbolism C_{21}	the capacity of industrial heritage to function as a symbol, embodying and representing specific cultural meanings, collective memories, zeitgeist, or regional characteristics.
	Cultural Identity C_{22}	Indicates the level of recognition, understanding, and acceptance by specific groups (e.g., local communities, industry practitioners) of the cultural values, historical significance embedded in the industrial heritage, and its role as part of their cultural identity.
	Emotional belonging and experience C_{23}	The ability of industrial heritage to evoke emotional connections in people and to provide the public with unique place-based experiences.
Social Value (B_3)	Social contribution to regional development C_{31}	The positive impact of the industrial heritage adaptive reuse project on the social development of its locality, for example: enhancing regional image and visibility, improving public space quality, and supporting community activities.
	Public participation C_{32}	Measures the extent and scope to which the public can be informed, consulted, involved, and even empowered in decision-making processes related to the conservation, adaptive reuse planning and design, operation, and management of industrial heritage.
	Enhancement of employment opportunities C_{33}	The quantity and quality of new jobs created directly or indirectly by the industrial heritage adaptive reuse project during both the implementation phase (renovation/ construction) and the operational phase.
Artistic Value (B_4)	Art aesthetics C_{41}	The aesthetic qualities and appeal of industrial heritage based on its visual characteristics, such as unique form, proportion, materiality, color, spatial composition, texture, light and shadow effects, which evoke a sense of beauty.
	Artistic design C_{42}	The level of design concept, creative conception, and artistic treatment manifested in the industrial heritage itself or in its adaptive reuse plan.
	Formal Style C_{43}	The characteristic morphological features, construction techniques, and artistic styles exhibited by the industrial heritage in its architecture, structures, equipment, etc.
Scientific and technological value (B_5)	Industry pioneering and influence C_{51}	Assesses whether the enterprise, factory, or technology represented by the industrial heritage held a pioneering or leading position in the history of its industry.
	Industrial technological advancement and representativeness C_{52}	Evaluates whether the industrial technology embodied or contained within the heritage was advanced for its time, and whether this technology serves as a typical and representative example within its industry, region, or type of industrial activity.

Table 2. (continued).

First-level indices	Second-level indices	Definitions
	Technology display degree C_{53}	The visibility, legibility, and potential for demonstration of the technological elements preserved within the industrial heritage, such as production processes, machinery, and structural systems.
Economic Value (B_6)	Environmental and Facility Remodeling Investment Costs C_{61}	The total capital investment required for environmental remediation, infrastructure upgrading, and basic facility adaptation to enable the safe adaptive reuse of the industrial heritage.
	Building Remodeling and Economic Expectations C_{62}	Assesses the technical feasibility and cost-effectiveness of the industrial heritage buildings to accommodate new functions. It also involves the projected assessment of the overall economic viability of the future reuse project based on this adaptability.
	Expected Returns C_{63}	The anticipated comprehensive benefits and returns from the industrial heritage reuse project. This includes direct economic returns and indirect social benefits, cultural benefits, and environmental benefits.
Environmental Value (B_7)	Appreciation C_{71}	The visual appeal and landscape value of the industrial heritage derived from its unique architectural appearance, spatial layout, environmental setting, or artistic treatments in its reuse, providing a positive viewing experience for the public.
	Environmental friendliness C_{72}	Measures the extent to which the industrial heritage reuse project minimizes its negative impacts on the natural environment and the built environment throughout its planning, design, construction, and operation phases.
	Greenness C_{73}	The proactive and active adoption of environmentally friendly technologies and strategies in the renovation and reuse of industrial heritage, aiming to reduce carbon footprint and ecological impact, and promote sustainable development.
Sustainable Value (B_8)	Appropriate protection and management systems C_{81}	The establishment of a scientific, comprehensive, and operational institutional framework for the effective conservation and sustainable reuse of industrial heritage.
	Feasibility of future changes C_{82}	Assesses the potential flexibility, adaptability, and provision within the spatial structure, facility systems, and planning framework of the reused industrial heritage after the initial reuse.
	Ecological and cultural sustainability C_{83}	The long-term ability to maintain ecological balance (resources, pollution control) while sustaining cultural values (heritage preservation, transmission) for industrial heritage reuse project.

S3) Normalize the vector $\overline{w} = (\overline{w}_1, \overline{w}_2, \cdots \overline{w}_n)$:

$$\frac{1}{w_i} = \frac{1}{\overline{w}_i} \times \sum_{i=1}^{n} \overline{w}_k,\ 1, 2, \cdots, 3 \tag{5}$$

S4) Calculate the ME:

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^{n} \left(\frac{1}{w_i} \times \sum_{j=1}^{n} a_{ij} w_j \right). \tag{6}$$

3.5 Consistency test for hierarchical single ordering and hierarchical total ordering

In order to verify whether the judgment matrix satisfies the consistency, this paper utilizes the consistency index [24] to test the judgment matrix. For a single level, the consistency index (CI) of the judgment matrix is defined as follows:

$$CI_i = \frac{\lambda_{\max} - n}{n - 1} \tag{7}$$

Table 3. Grade standard for AIHRV.

Score range	$0 \leq S < 1.5$	$1.5 \leq S < 2.5$	$2.5 \leq S < 3.5$	$3.5 \leq S < 4.5$	$S \geq 4.5$
Judging results	Very poor	Poor	Average	Good	Very good
Value assessment	No value D_1	Low value D_2	Medium value D_3	Valuable D_4	Very valuable D_5

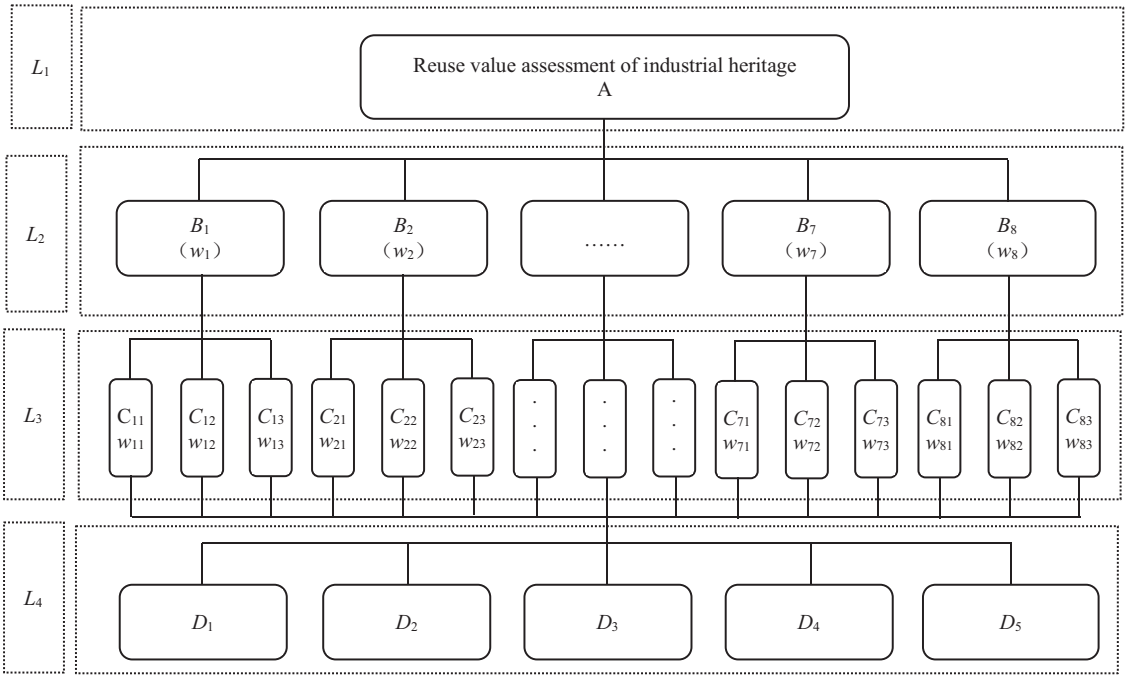

Fig. 1. Hierarchical model for assessing the reutilization value.

Table 4. Evaluation scale of analytic hierarchy process.

Comparison criteria	Evaluation scale of Factor i to factor j
1	Equally Importance
3	Moderately More Importance
5	Strongly More Importance
7	Very Strongly Importance
9	Extremely Importance
2, 4, 6, 8	Middle values

where is $\lambda_{\max}$ the ME; n is the order of the judgment matrix.

In order to overcome the influence of different scales, this paper adopts consistence ratio (CR) to characterize the consistency evaluation index, in which the consistency test is considered to be satisfied (i.e., judgment matrix A has consistency) if $CR < 0.1$. CR_i of the ith judgment matrix is calculated as follows:

$$CR_i = \frac{CI_i}{RI_i} = \frac{\lambda_{maxi} - n_i}{(n_i - 1) \times RI_i} \tag{8}$$

where RI is the random consistency index (RCI), and its value is shown in Table 6.

In order to evaluate the consistency of the hierarchical total ordering results, similar to the hierarchical single ordering, a consistency test is also required, then the CI, RI and CR_{Totall} of the hierarchical total ordering results can be calculated by the following formula:

$$CI = \sum_{i}^{m} w_i \times CI_i \tag{9}$$

$$RI = \sum_{i}^{m} w_i \times RI_i \tag{10}$$

$$CR_{Totall} = \frac{CI}{RI} = \frac{\sum_{i}^{m} w_i \times CI_i}{\sum_{i}^{m} w_i \times RI_i} \tag{11}$$

where w_i is the factor weight of the first layer (i.e., first-level layer).

Table 5. Index judgment matrix of industrial heritage assessment value.

S	L_1	L_2	. . .	L_j	. . .	L_{n-1}	L_n
L_1	a_{11}	a_{12}	. . .	. . .	. . .	a_{1n-1}	a_{1n}
L_2	a_{21}	a_{22}	. . .	. . .	. . .	$a_{2(n-1)}$	a_{2n}
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
L_i	a_{i1}	a_{i2}	. . .	a_{ij}	. . .	$a_{i(n-1)}$	a_{in}
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
L_{n-1}	$a_{(n-1)1}$	$a_{(n-1)2}$	. . .	. . .	. . .	$a_{(n-1)(n-1)}$	$a_{(n-1)n}$
L_n	a_{n1}	a_{n2}	. . .	. . .	. . .	$a_{n(n-1)}$	a_{nn}

Table 6. Random consistency index.

Order of matrix	3	4	5	6	7	8
RI	0.58	0.89	1.12	1.24	1.32	1.41
Order of matrix	9	10	11	12	13	14
RI	1.45	1.49	1.52	1.54	1.56	1.58

3.6 Flowchart for assessing RIH

In order to assess the reutilization value of industrial heritage using hierarchical analysis, the flowchart of this assessment process is given in Figure 2. Firstly, judgment matrices of the target level on the first-level indices (i.e., historical value, cultural value, social value, artistic value, economic value, environmental value and sustainable value) and the judgment matrices of the second-level indices (e.g., the judgment matrices of C_{11}, C_{12} and C_{13}) are constructed. Secondly, the ME of each judgment matrix is calculated and the consistency of the judgment matrices is checked. Subsequently, the reutilization value of industrial heritage is assessed based on the scores of the secondary indices and their weights.

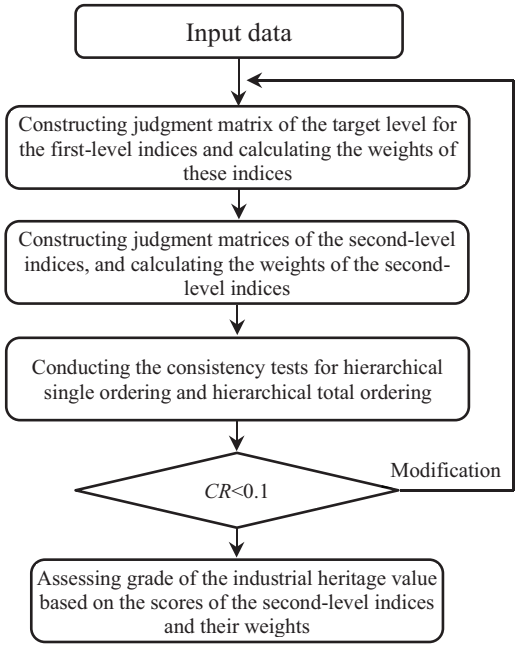

Fig. 2. Flowchart for assessing the reutilization value of industrial heritage.

4 Case studies

4.1 Constructing judgment matrices of first-level and second-level indices

This paper selects an industrial heritage to analyze the application of the proposed method. A renovation centered on a "culture+" strategy was carried out for this industrial heritage, preserving industrial relics such as watchtower, dome workshop, and red-brick factories without large-scale demolition, and forming the current industrial heritage reutilization.

Based on the nine-level scale method, we constructed the judgment matrix of first-level indices (shown in Tab. 7) and eight judgment matrices of second-level indices (shown in Tabs. 8–15) for the assessment of reutilization value of industrial heritage, and calculated the weights of each factor of the first-level indices and each factor of the second-level indices according to the hierarchical analysis method.

4.2 Calculating the ME of judgment matrix

In this paper, the ME of the judgment matrix is calculated according to the square root method, and the ME of the judgment matrix of the first-level indices and the judgment matrix of the second-level indices is shown in Figure 3, in which the ME of the judgment matrix A is 8.576, and the MEs of the judgment matrices of the eight second-level indices are 3.086, 3.004, 3.044, 3.004, 3.094, 3.086, 3.094 and 3.018.

Table 7. Judgement matrix and weight coefficient for first-level indices A.

A	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	**ω**
B_1	1	1	3	3	3	2	1	1/2	0.1615
B_2	1	1	3	5	5	1	1	1/2	0.1683
B_3	1/3	1/3	1	5	5	1	1/2	1/2	0.1022
B_4	1/3	1/5	1/5	1	1	1/5	1/4	1/2	0.0393
B_5	1/3	1/5	1/5	1	1	1/2	1/4	1/3	0.0419
B_6	1/2	1	1	5	2	1	1/2	1/3	0.1046
B_7	1	1	2	4	4	2	1	1/2	0.1650
B_8	2	2	2	2	3	3	2	1	0.2171

Table 8. Judgement matrix and coefficient for historical value B_1.

B1	C_{11}	C_{12}	C_{13}	**ω**
C_{11}	1	1/5	1/6	0.0821
C_{12}	5	1	2	0.5498
C_{13}	6	1/2	1	0.3681

Table 9. Judgement matrix and coefficient for cultural value B_2.

B2	C_{21}	C_{22}	C_{23}	**ω**
C_{21}	1	1/5	1/6	0.0836
C_{22}	5	1	1	0.4443
C_{23}	6	1	1	0.4721

Table 10. Judgement matrix and coefficient for social value B_3.

B3	C_{31}	C_{32}	C_{33}	**ω**
C_{31}	1	3	1/5	0.1830
C_{32}	1/3	1	1/8	0.0752
C_{33}	5	8	1	0.7418

Table 11. Judgement matrix and coefficient for artistic value b_4.

B4	C_{41}	C_{42}	C_{43}	**ω**
C_{41}	1	1/3	1/5	0.1095
C_{42}	3	1	1/2	0.3090
C_{43}	5	2	1	0.5816

Table 12. Judgement matrix and coefficient for scientific and technological value B_5.

B5	C_{51}	C_{52}	C_{53}	**ω**
C_{51}	1	6	3	0.6348
C_{52}	1/6	1	1/5	0.0780
C_{53}	1/3	5	1	0.2872

Table 13. Judgement matrix and coefficient for economic value B_6.

B6	C_{61}	C_{62}	C_{63}	**ω**
C_{61}	1	1/5	1/6	0.0821
C_{62}	5	1	2	0.5498
C_{63}	6	1/2	1	0.3681

Table 14. Judgement matrix and coefficient for environmental value B_7.

B7	C_{71}	C_{72}	C_{73}	**ω**
C_{71}	1	1/3	1/6	0.0881
C_{72}	3	1	1/5	0.1947
C_{73}	6	5	1	0.7172

Table 15. Judgement matrix and coefficient for sustainable value B_8.

B8	C_{81}	C_{82}	C_{83}	**ω**
C_{81}	1	2	1/3	0.2970
C_{82}	1/2	1	1/4	0.1634
C_{83}	3	4	1	0.5396

4.3 Consistency test of judgement matrix

In order to verify whether the judgment matrix meets the consistency, this paper uses the consistency index to test the judgment matrix, then the hierarchical single sorting index *CI* and *CR* values of the first-level and second-level indices are shown in Figure 4. In Figure 4, the CR value of judgment matrix A is 0.05834, and the CR values of the eight second-level indices judgment matrices are 0.06315, 0.00318, 0.03799, 0.00318, 0.08105, 0.07394, 0.08105, and 0.00793, respectively. It can be seen that the hierarchical single-ordered consistency test CR values are all less than

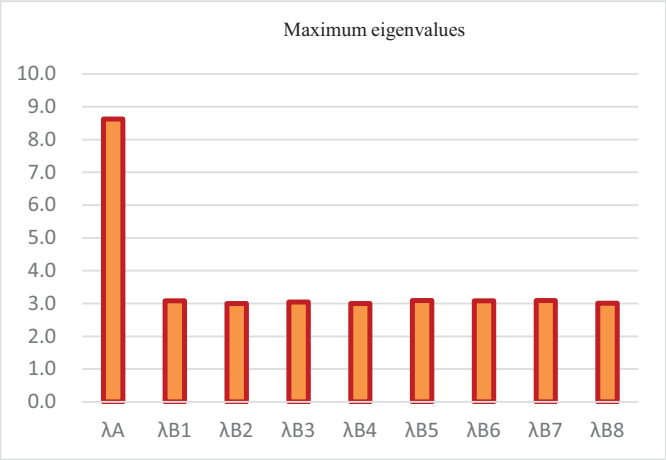

Fig. 3. The MEs of judgment matrix for first-level and second-level indices.

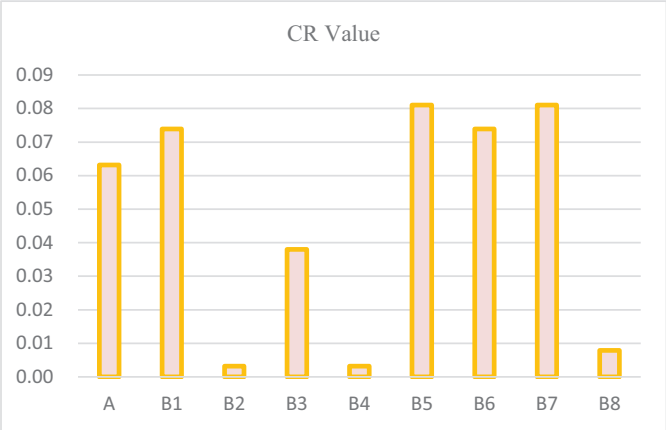

Fig. 4. Hierarchical single ordering index CR value.

0.1. Therefore, the judgment matrix of first-level indices and the judgment matrix of second-level indices constructed in this paper meet the consistency test requirements.

On the basis of the above calculation process, the indices and their weight coefficients of the AIHRV have been obtained, as shown in Table 16. It can be seen from Table 16 that: 1) the maximum and minimum weight coefficients for the first-level indices are 0.2171 (the sustainable value) and 0.0393 (the artistic value), and it indicates that the sustainable value has a higher care; 2) the maximum and minimum weight coefficients for the second-level indices are 0.11717 and 0.00327.

4.4 Reutilization value assessment results of industrial heritage

According to the scoring method of experts, the individual scores of 24 second-level indices (C_{ij}, $i = 1, 2, 3, ..., 8$; j=1, 2, 3) of AIHRV are determined, as shown in Figure 5. Then, according to the AIHRV level criteria and the respective weight coefficients of the second-level indices, the score of each second-level index is multiplied with its corresponding weight coefficient, and then the weighted scores are summed up to get the weighted score of the industrial heritage. The score of the case selected in this paper is 4.3186, and according to the five AIHRV grades set in this paper (i.e., poor ($S < 1.5$), poor ($1.5 \leq S < 2.5$), average ($2.5 \leq S < 3.5$), good ($3.5 \leq S < 4.5$), and very good ($S \geq 4.5$)), it can be seen that the reutilization value of this industrial heritage is assessed as D_4 (i.e., valuable).

5 Conclusions

The reutilization value assessment of industrial heritage has a great significance to the protection and sustainable development of industrial heritage. Therefore, this paper comprehensively considers 8 first-level indices (i.e., historical value, cultural value, social value, artistic value, scientific and technological value, economic value, environmental value, and sustainable value) and 24 secondary indicators (e.g., historical era, cultural symbolism, and public participation, etc.), and this paper proposes an assessment of industrial heritage reutilization value based on the hierarchical analysis method by comprehensively considering eight indicators. Firstly, this paper puts forward the index system of AIHRV and establishes the hierarchical standard of AIHRV. Secondly, it puts forward the method of AIHRV based on hierarchical analysis, including: establishing the hierarchical structure model of AIHRV, constructing the judgment matrix of industrial heritage value assessment indices, calculating the ME of the judgment matrix by square root method, consistency test of the hierarchical single ranking and the hierarchical total ranking, and so on. Thirdly, combining with the criteria of AIHRV level, the subjective scoring method and objective weight assessment method are considered to solve the reutilization value assessment level of the industrial heritage. Finally, the validity of the proposed method is verified through the case study, and the following conclusions are obtained:

- The AIHRV method based on the hierarchical analysis method proposed in this paper can effectively take into account the differentiated impacts of various factors;
- According to the results of the data taken from the case study in this paper, the weight coefficient of the sustainable value is the highest among the first-level indices (0.2171), and the combined weight coefficient of the green environmental protection is the highest among the second-level indices (0.11834), which are more worthy of attention. These factors are more worthy of attention;
- After comprehensive subjective and objective assessment, the reutilization value of industrial heritage obtained from the data taken in the case of this paper is assessed as D4, which indicates that the development of this industrial heritage is good.

Although the proposed method can assess the reutilization value of industrial building heritage, it also has application limitation (like judgment bias or inconsistency). Thus, a research work aiming at these aspects will be implemented in the future work.

Table 16. Indices and weight coefficients for assessing the RIH.

Target	First-level indices	Weight coefficients	Second-level indices	Weight coefficients
A	Historical value (B_1)	0.1615	Historical Era C_{11}	0.01327
			Historical background information C_{12}	0.08881
			Relevance to historical figures and events C_{13}	0.05945
	Cultural value (B_2)	0.1683	Cultural symbolism C_{21}	0.01407
			Cultural Identity C_{22}	0.07477
			Emotional belonging and experience C_{23}	0.07946
	Social Value (B_3)	0.1022	Social contribution to regional development C_{31}	0.01870
			Public participation C_{32}	0.00769
			Enhancement of employment opportunities C_{33}	0.07583
	Artistic Value (B_4)	0.0393	Art aesthetics C_{41}	0.00430
			Artistic design C_{42}	0.01215
			Formal Style C_{43}	0.02287
	Scientific and technological value (B_5)	0.0419	Industry pioneering and influence C_{51}	0.02661
			Industrial technological advancement and representativeness C_{52}	0.00327
			Technology display degree C_{53}	0.01204
	Economic Value (B_6)	0.1046	Environmental and Facility Remodeling Investment Costs C_{61}	0.00859
			Building Remodeling and Economic Expectations C_{62}	0.05750
			Expected Returns C_{63}	0.03849
	Environmental Value (B_7)	0.1650	Appreciation C_{71}	0.01453
			Environmental friendliness C_{72}	0.03212
			Greenness C_{73}	0.11834
	Sustainable Value (B_8)	0.2171	Appropriate protection and management systems C_{81}	0.06448
			Feasibility of future changes C_{82}	0.03549
			Ecological and cultural sustainability C_{83}	0.11717

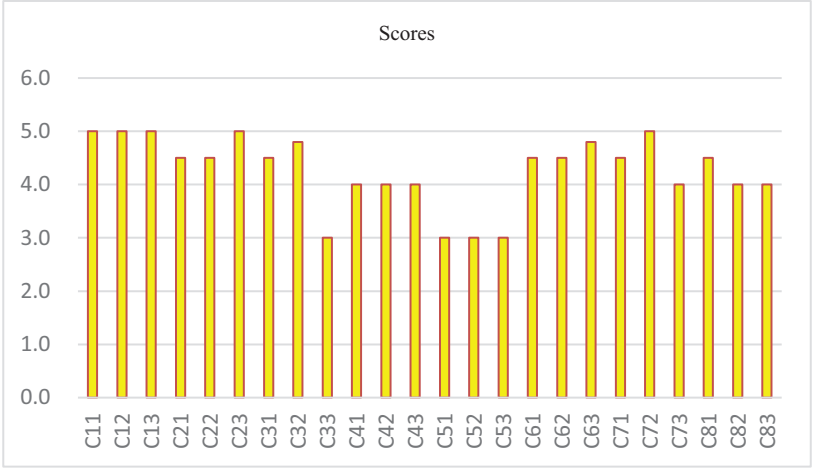

Fig. 5. Scores for 24 second-level indices.

Funding

This work is supported by Anhui Provincial Research Project for Higher Education Institutions (No. 2024AH040324).

Conflicts of interest

The author declares no conflict of interests.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author contribution statement

Wenjun Zhang designed research, performed research, analyzed data, wrote and revised the paper.

References

1. E. Bertacchini, V. Frontuto, Economic valuation of industrial heritage: a choice experiment on Shanghai Baosteel industrial site, J. Cult. Heritage. **66**, 215–228 (2024)
2. P. Guo, Q. Li, H. Guo et al., Quantifying the core driving force for the sustainable redevelopment of industrial heritage: Implications for urban renewal, Environ. Sci. Pollut. Res. **28**, 48097–48111 (2021)
3. A. Li, W.B.A. Wahid, M.J.B.M. Isa, et al. Economic value assessment of industrial heritage in Tangshan, China, J. Infrastruct. Policy Dev., **8**, 3568 (2024)
4. P. Zhang, M. Xiang, T. Zhang et al., Study on comprehensive value of industrial heritage in Yuejin Road historic district based on GIS technology, Open J. Social Sci. **9**, 440–454 (2021)
5. M.R. Blagojević, A. Tufegdžić, The new technology era requirements and sustainable approach to industrial heritage renewal, Energy Build. **115**, 148–153 (2016)
6. X. Somoza-Medina, O. Monteserín-Abella, The sustainability of industrial heritage tourism far from the axes of economic development in Europe: two case studies, Sustainability **13**, 1077 (2021)
7. M. Oglethorpe, The Rolt Memorial Lecture 2013: the public benefit of industrial heritage—taking a positive view, Ind. Archaeol. Rev. **36**, 85–96 (2014)
8. S. De Gregorio, M. De Vita, P. De Berardinis et al., Designing the sustainable adaptive reuse of industrial heritage to enhance the local context, Sustainability **12**, 9059 (2020)
9. S. Samadzadehyazdi, M. Ansari, M. Mahdavinejad et al., Significance of authenticity: learning from best practice of adaptive reuse in the industrial heritage of Iran, Int. J. Archit. Heritage **14**, 329–344 (2020)
10. N. Lu, M. Liu, R. Wang, Reproducing the discourse on industrial heritage in China: reflections on the evolution of values, policies and practices, Int. J. Heritage Stud. **26**, 498–518 (2019)
11. F. Gharaati, M. Mahdavinejad, A. Nadolny, H. Bazazzadeh, Sustainable assessment of built heritage adaptive reuse practice: iranian industrial heritage in the light of international charters, Historic Environ.: Policy Practice, **14**, 498–532 (2023)
12. Q. Zhao, F. Liu, Y. Yang, An approach to assess the value of industrial heritage based on Dempster-Shafer theory, J. Cult. Heritage. **32**, 210–220 (2018)
13. J. Claver, A. García-Domínguez, M.A. Sebastián, Multicriteria decision tool for sustainable reuse of industrial heritage into its urban and social environment, Case studies, Sustainability **12**, 7430 (2020)
14. F. Meng, Y. Zhi, Y. Pang, Assessment of the adaptive reuse potentiality of industrial heritage based on improved entropy TOPSIS method from the perspective of urban regeneration, Sustainability **15**, 7735, (2023)
15. Y. Li, L. Zhao, J. Huang et al., Research frameworks, methodologies, and assessment methods concerning the adaptive reuse of architectural heritage: a review, Built Herit. **5**, 1–19 (2021)
16. P. Bai, Y. Zhao, Conservation design of industrial heritage based on nonlinear ga optimization algorithm and three-dimensional reconstruction, Scalable Comput.: Pract. Exp. **25**, 874–882 (2024)
17. X. Zhu, X. Han, M. Xie et al., Concept and application of industrial heritage planning decision in big data era, Scalable Comput.: Practice Exp. **25**, 1894–1903 (2024)
18. C. Agaliotou, Reutilization of industrial buildings and sites in Greece can act as a lever for the development of special interest/alternative tourism, Procedia Soc. Behav. Sci. **175**: 291–298 (2018)
19. D.A. Elsorady, Assessment of the compatibility of new uses for heritage buildings: the example of Alexandria national museum, Alexandria, Egypt, J. Cult. Heritage. **15**, 511–521 (2014)
20. T. Hartmann, G.E. Gürcanlı, M. Nurkaliyev, M. Özgür, Industrial heritage restoration/renovation projects and their societal impacts: case of Gasholder Restoration Projects, Societal Impacts. **3**, 100062 (2024)
21. F.C. Merciu, A.L. Cercleux, G.-L. Merciu. Models of technical and industrial heritage re-use in Romania, Proc. Environ. Sci. **14**, 216–225 (2012)
22. A. Ishizaka, A. Labib, Review of the main developments in the analytic hierarchy process, Expert Syst. Appl. **38**, 14336–14345 (2011)
23. S. Kumar, N. Parashar, A. Haleem, Analytical hierarchy process applied to vendor selection problem: small scale, medium scale and large scale industries, J. Bus. Intell. **2**, 355–362 (2009)
24. J. Franek, A. Kresta, Judgment scales and consistency measure in AHP, Proc. Econ. Finance **12**, 164–173 (2014)

Cite this article as: W. Zhang: Reutilization value assessment approach for industrial building heritage based on hierarchical analysis process. Sust. Build. **8**, 5 (2025). https://doi.org/10.1051/sbuild/2025007